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# PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION under 37 CFR §1.53(c).

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☐ Additional inventors are being named on the _____ separately numbered sheets attached hereto.

**TITLE OF THE INVENTION (500 characters max)**

## A METHOD OF CURING CONCRETE STRUCTURES

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**ENCLOSED APPLICATION PARTS (check all that apply)**

■ Specification – Number of Pages: 7 ☐ CD(s), Number – ____

■ Drawing(s) – Number of Sheets: 5 ☐ Other (specify) – ____________

☐ Application Data Sheet. See 37 CFR 1.76

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■ Applicant claims small entity status. See 37 CFR 1.27.

■ A check or money order is enclosed to cover the filing fees.

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

■ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are: ____________

Respectfully submitted,

SIGNATURE Richard Himelhoch Date: June 4, 2003

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# A METHOD OF CURING CONCRETE STRUCTURES


## ABSTRACT

A method of accelerating the cure of concrete structures using intralaminar heat generated by applying electrical energy to electrically conductive, non-metallic members disposed within the structures. The method further incorporates the electrically conductive, non-metallic members as internal reinforcement in the cured, finished structure reducing or obviating the need for reinforcing steel. The electrically conductive, non-metallic members are provided in various forms, including but not limited to, pliable forms impregnated with a polymer resin matrix capable of being rigidified and fully rigidified forms. A preferred embodiment of the method according to the invention is an expedited cure of a concrete wall panel for use in tilt-up construction.


## BACKGROUND OF THE INVENTION

The present invention relates generally to a method for expediting the cure of concrete structures and more particularly to the curing of large concrete wall panels used in *tilt-up* construction practices. One of the advantages of the tilt-up process is the shortened construction times; often only requiring 4 – 6 weeks for completion. Certain disadvantages exist though in the limitations in geometry due to the inherent properties of concrete reinforced with steel. In tilt-up construction, relatively thin (3.0" – 8.0") wall panels are cast horizontally at ground level and raised into the vertical position by tilting the panel about one end by lifting from the opposite end. The structure is then lifted into a final position to form a structural wall element. Typically, this procedure is performed at the building site with the forms and molding surfaces constructed atop the floor slab, which has first been poured on a prepared subgrade. With the molding forms positioned, steel reinforcing members are located within the panel area and concrete in poured or pumped into the area defined by the forms. Before the wall elements can be erected, sufficient time must be allowed for the concrete to gain enough strength to withstand the lifting stresses. Concrete reacts with water to form chemical compounds that strengthen the concrete. The speed at which this *hydration reaction* occurs is dependent on time and temperature. At a minimum ambient temperature of 73°F, a waiting period of between five and ten days must be observed to allow the concrete to attain at least 75% of the design strength (usually 2500-PSI compressive strength). This process is slowed considerably at temperatures below 73°F resulting in cost increases and scheduling delays.

Another construction method for producing large, concrete structures involves the casting or molding of the structures at a central location. Once a satisfactory strength level is achieved, the structures are removed from their molds and transported to the erection site. This process does lend itself to a somewhat more controlled environment but does not provide for ideal curing conditions. Large and irregular shaped structures comprising concrete must still observe the basic hydration reaction schedules and are typically less cost effective due to transportation costs. Construction of concrete structures during extreme cold may even become impossible because the water, necessary for cure, can freeze at low ambient temperatures.

In order to accelerate the curing of concrete structures, it has become customary to incorporate additives into the concrete mixture to prevent or retard freezing and alternately provide a heating means so that the concrete will cure more rapidly and thereby facilitate an increase in productivity. Other methods simply employ thermally insulated blankets or covers to contain some of the heat generated naturally by the hydration reaction process. Heating means have historically been through the introduction of steam or pressurized, heated water into an enclosure surrounding the curing structures, the use of tubes or conduits that convey a heat transfer medium from a central boiler unit to the surface of the structure or its surrounding mold or form, and even electrically heated molds and forms. All of these methods though they addressed the problems with novel and somewhat effective means, are labor intensive and fail to provide an inexpensive, expedient cure mechanism for concrete structures. A heat transfer must still take place from the heat source through conveyance apparatuses and ultimately through the cross sectional area of the concrete structure in order to accelerate the cure. This process suffers from exorbitant heat loss to the atmosphere. The apparent need exists for a concrete heating method that is energy efficient and economical to implement; ultimately reducing cycle times, labor and finished construction costs.

It is the principal objective of the present invention to demonstrate an efficient means for introducing heat to concrete structures to accelerate the cure while simultaneously providing internal reinforcement to the completed component. The invention resides in not any one of these features individually but in the synergistic combination of all its structures and processes.

SUMMARY OF THE INVENTION

The present invention relates to a method for heating concrete structures from within the structure itself. By strategically placing electrically conductive, non-metallic members through the thickness of a concrete structure, it is possible to exploit the electrical resistivity of these members and

employ them as heating members. The internal positioning of the heating members also affords a synergistic result in that these members remain as reinforcement in the finished structure. When the heating members used are comprised of carbon fibers, the resultant reinforcing properties are equal to that of steel reinforcement.

In the construction of a wall element, such as in tilt-up construction, the carbon fibers are presented in the form of a three dimensional profile impregnated with a polymer resin matrix compatible with the alkaline concrete environment and capable of rigidifying with the addition of the heat produced in the curing operation disclosed. The initial pliability of the members allows for quick and easy distribution within the forming mold. The heating members are arranged in a continuous sequence or are individually placed throughout the structure. In one embodiment of the invention, conductive contact members are removably attached to the internal surfaces of the forming mold at locations corresponding to the median point in the wall thickness before the heating members are positioned and the concrete is poured. These contact members serve as connection points for the pliable members as they are arranged in the structure to ensure correct positioning and to communicate electrical energy from a power supply to the heating members. Other forms of connection can be used, depending on the geometry of the structure, including continuous buss bars and a roller system positioned outside of the form walls that the accumulate the pliable heating members and provide tension to ensure that the heating stratum is medially positioned. The heating members discussed can also be provided in a rigidified form. In this scenario, the members can be handled in the same manner as traditional steel reinforcing materials. Opposing ends of the rigid members are allowed to protrude through the form walls for similar communication to the electrical power source or are connected to the contact members in a similar configuration described. The heating members are located medially to provide a consistent heat profile through the thickness of the structure and have a substantial surface area affording adequate contact with the surrounding concrete wherein the thermal energy produced is conducted directly into the surrounding concrete. By introducing heat to a concrete structure using the aforementioned process, curing cycles can be reduced by as much as 66%. The design of the heating members is flexible in that carbon fiber content, polymer content and profile geometry can be calculated and modified to provide a specific surface area, meet specific cost and electrical requirements and supply the necessary strength and rigidity to the structure. By introducing heat to the medial portion of a concrete wall panel or structure using the above described invention, thermal energy is efficiently transferred to the concrete without any loss to the atmosphere resulting in faster cure cycles and reduced energy requirements translating to increased productivity and cost savings. A synergistic benefit of the invention is the ability to minimize or

obviate the need for reinforcing steel by employing the structural properties of the heating members again relieving installation costs and affording a degree of flexibility in design.

These and other novel features and advantages of the present invention will be apparent from the following description of the embodiments with reference to the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an isometric view of a typical tilt-wall forming arrangement depicting the perimeter forming members and the traditional steel reinforcing members in place.

FIG. 2 is an isometric view of a tilt-wall forming arrangement depicting the use of the heating members described in the invention and a connection method for communicating electrical power from a power supply to the heating members.

FIG. 3 is an enlarged cross-sectional view of a forming wall and a removably attached electrical connection.

FIG. 4 is a cross-sectional view of a heating element formed into a three-dimensional profile.

FIG. 5 is a plan view of a typical heating member arrangement depicting the heating members in a continuous circuit.

## DETAILED DESCRIPTION OF THE INVENTION

Our invention generally provides a means for heating concrete panels for tilt-up wall construction employing embedded members within the concrete structure to provide heat and remain permanently intact to remain as structural reinforcement. FIG. 1 depicts a typical concrete forming arrangement used in tilt-up wall construction. Concrete 1 is shown partially filled within a panel forming arrangement defined by perimeter forms 3. Support blocks 4 are situated to provide lateral support to forms 3 and to enable the forms to withstand the forces of pouring concrete without distorting the desired geometry. Steel reinforcing wires 2 are shown in a typical configuration. Because concrete panels built using this construction technique must be afforded sufficient time to reach a less than complete level of cure before tilting into position, additional reinforcing steel 2 must be added to withstand the stresses of tilting. In FIG. 2, a concrete wall forming arrangement is shown with heating members 5 replacing the steel reinforcements shown in FIG. 1. The members 5 communicate with electrical contacts 6 penetrating through forms 3 to allow connection with a power supply (not shown). Based on the actual tensile properties needed

in the finished structure, heating members are designed to provide the structural reinforcement as well. FIGURES 1 – 3 portray the heating element as a generally cylindrical member that can be conveniently spooled and easily handled on site. In this embodiment, the heating element 5 is supplied in this cylindrical or rope like profile with other possible embodiments being a 'C' channel, rectangular or any other custom designed shape specific to the site application and requirements. The heating element 5 comprises a plurality of carbon fibers or filaments impregnated with a resin matrix capable of rigidifying with the application of heat. A suitable resin matrix is Dion 6694 vinyl ester combined with RD 1070 thickening agent from Reichhold Chemicals. In order to provide extended shelf life, a latent initiator package is used that allows 30 days of shelf life at cool, storage temperatures. A catalyst package consummate with this objective is a 1% concentration by weight of both Trigonox 29-B75 and Trigonox 21 available from Axzo Nobel. Resin impregnation takes place off site and the heating members are shipped to the installation site. In another embodiment, the heating member 5 is impregnated with a thermoplastic resin matrix or comingled with thermoplastic fibers. This arrangement affords unlimited shelf life and remains pliable until the heat generated during concrete processing sets the thermoplastic resin or fiber combination. Once cooled, the heating member rigidifies providing structural reinforcement in the finished concrete structure. In yet another embodiment, the heating members are supplied in a previously rigidified form. Here the members are handled much like traditional reinforcing steel with the exception of providing a means to communicate electrical energy to the members. Rigidification in this embodiment can be the result of either a thermoset or thermoplastic resin matrix combined with the carbon fibers. FIG. 3 demonstrates a cross sectional view of a typical electrical connection as seen in FIG. 2 along lines A -- A. In this view, the electrical contact assembly comprising a gripping apparatus 7 for the carbon fiber heating member 5. This interface conveys electrical energy from an external power supply (not shown) through contact 9. This member has an externally threaded portion to accept a fastener. The fastener rod 8 has a thinned section 11 where, after the concrete is cured and forms stripped, the rod can be easily snapped off and removed within the conical area formed by the recess forming shoe 10. In a typical wall forming operation, forms 3 are assembled to define the perimeter of the structure. The carbon fiber heating elements 5, which are the object of this invention, are arranged within the cavity defined by the forms. FIG. 5 shows one such arrangement. The arrangement is dictated by the amount of heat energy necessary to expedite the curing process as well as by the finished mechanical properties of the wall. Because a wall section cured using the method described will attain a higher degree of cure in a shorter time frame, the actual reinforcing requirements for tilting the wall into position can be reduced. Similarly, design requirements such as wind load,

opening supports and buckling can be easily met with the addition of a limited amount of high strength carbon fiber heating members. In FIG. 5, the heating members are arranged in a continuous fashion wherein electrical contact is only required in two locations **12a** and **12b**. This embodiment also facilitates the simultaneous curing of several wall panels or structures by connecting the panels in series or parallel circuits.

## CLAIMS

1. What we claim is a resin impregnated non-metallic structural fiber architecture to replace the metal reinforcement of concrete walls, structures and building panels. The non-metallic fiber architecture will be electrically charged to solidify the fiber and generate heat radially to improve the time to set or cure the "green" concrete.
2. Resin impregnate nonmetallic structural fiber architecture is impregnated with a catalyzed thermoset resin.
3. The resin impregnated nonmetallic structural fiber architecture of claim of 1 is carbon fiber.
4. The resin impregnated nonmetallic structural fiber architecture of claim 1 is a 12K carbon fiber tow.
5. The resin impregnated nonmetallic structural fiber architecture of of 1 is a 24K carbon fiber tow.
6. The resin impregnated nonmetallic structural fiber architecture of 1 is a 48K carbon fiber tow.
7. The resin impregnated nonmetallic structural fiber architecture of 1 is an 80K carbon fiber tow.
8. The resin impregnated nonmetallic structural fiber architecture of 1 is a 96K carbon fiber tow.
9. The claim is commingled with thermoplastic filaments and 12K carbon fiber.
10. The thermoplastic fiber of claim 9 is nylon 6 and 12K carbon fiber.
11. The thermoplastic fiber of claim 9 is nylon 12 and 12K carbon fiber.
12. The thermoplastic fiber of claim 9 is polyethylene and 12K carbon fiber.
13. The thermoplastic fiber of claim 9 is polypropylene and 12K carbon fiber.
14. The thermoplastic/carbon architecture can be installed in the form and cured prior to the introduction of the uncured concrete.
15. The concrete cure is accelerated by "reheating" the cured carbon resin matrix to 120' F.
16. The thermoset resin matrix/carbon architecture is cured in place concurrently raising the temperature within the "green" concrete to 120'F to complete the concrete cure process.
17. The bundles of carbon tows are mechanically wound to meet the strength requirements of the steel, which is removed.
18. The consolidated bundles of carbon are attached at opposing ends to a buss bar.
19. The buss bar of claim 18 is the electric contact point through which the electric power is driven to generate 120'F for two hours which is sufficient to activate the hydration reaction while not reducing its initiation/cure effect.
20. The consolidated bundles of carbon may be looped at opposing ends creating a continuous filament of impregnated carbon fiber.
21. The carbon fiber can be mechanically consolidated by weaving.
22. The carbon fiber can be mechanically consolidated by stitch bonding.
23. The carbon fiber can be mechanically consolidated by knitting.
24. The carbon fiber can be mechanically consolidated by braiding.
25. The cured concrete structure can be heated after the structure is constructed to provide radiant heat to the finished structure.
26. The structure of claim 25 is a wall.
27. The structure of claim 25 is a floor.
28. The structure of claim 25 is a ceiling
29. The floor of claim 25 may serve as the heated pouring slab to radially heat the concrete structure formed upon it.
30. The heated pouring slab could cure concrete walls, ceilings, precast parts, precast pipe, and prestress beams and decks.

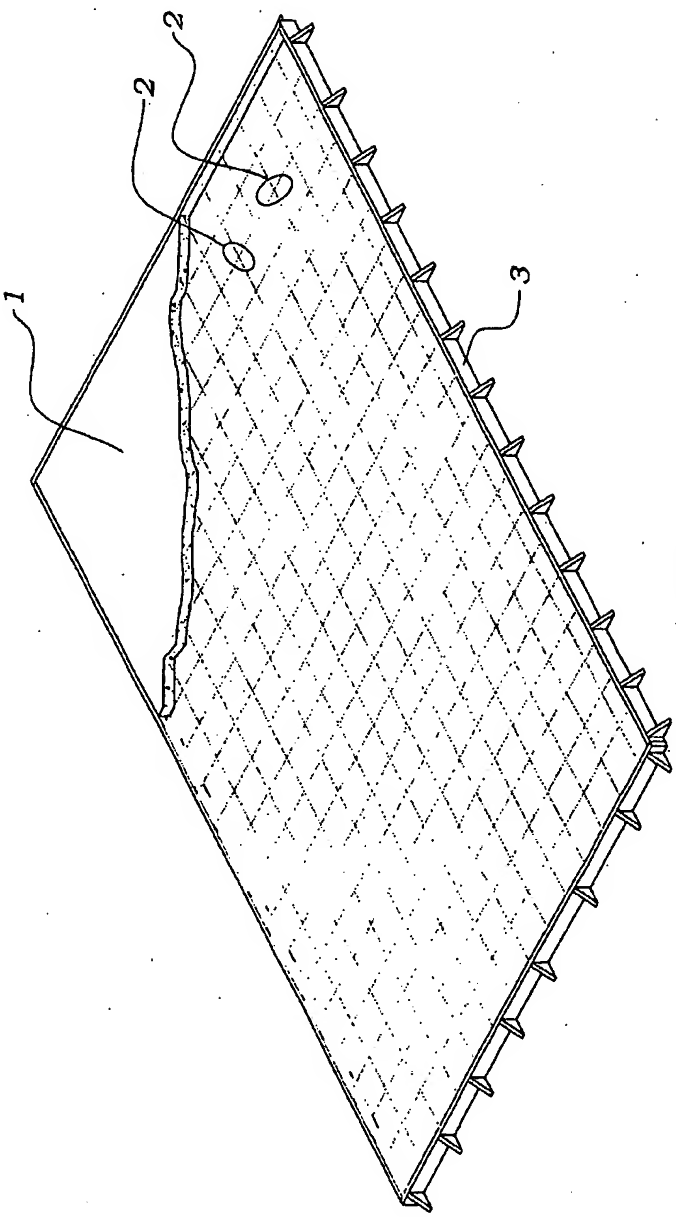


FIG. 1

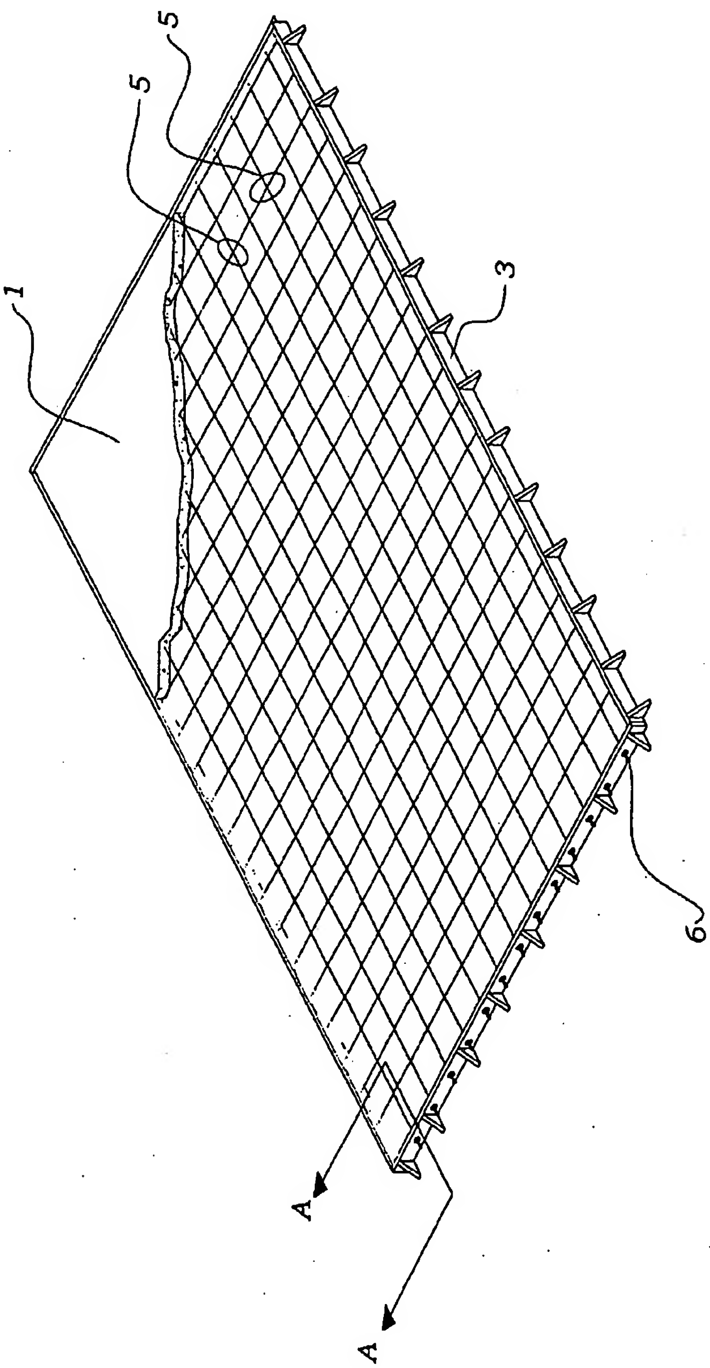


FIG. 2

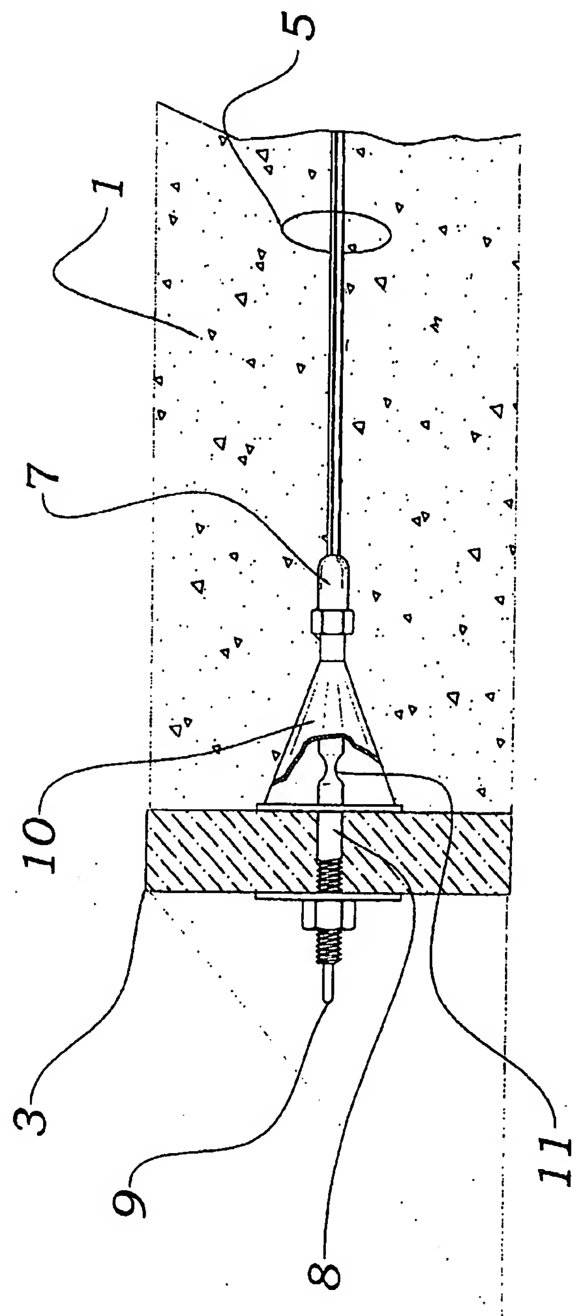


FIG. 3

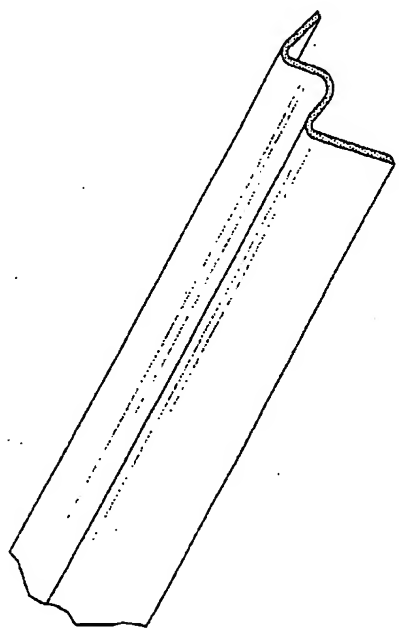

FIG. 4

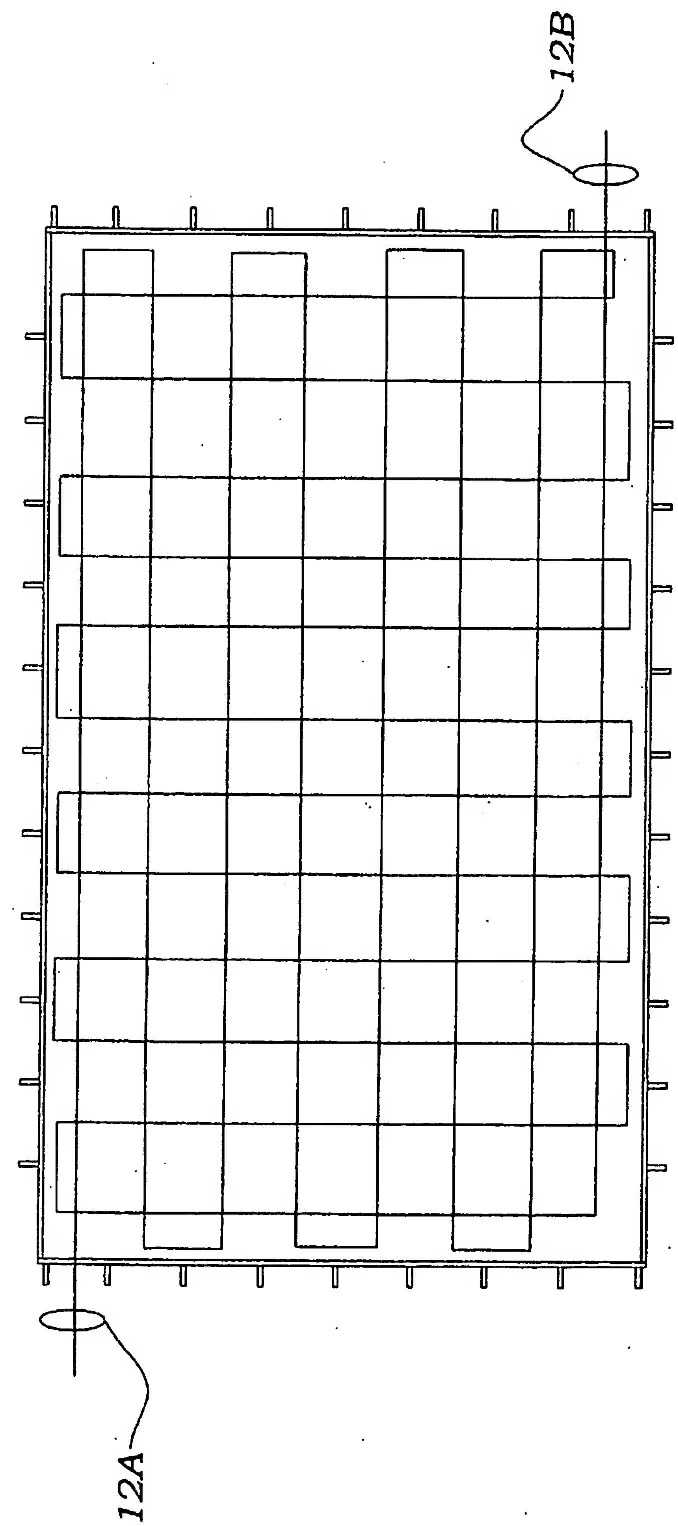


FIG. 5